Astrophysical neutrinos from AGN coronae

QUARKS-2024 Seminar 20 May 2024

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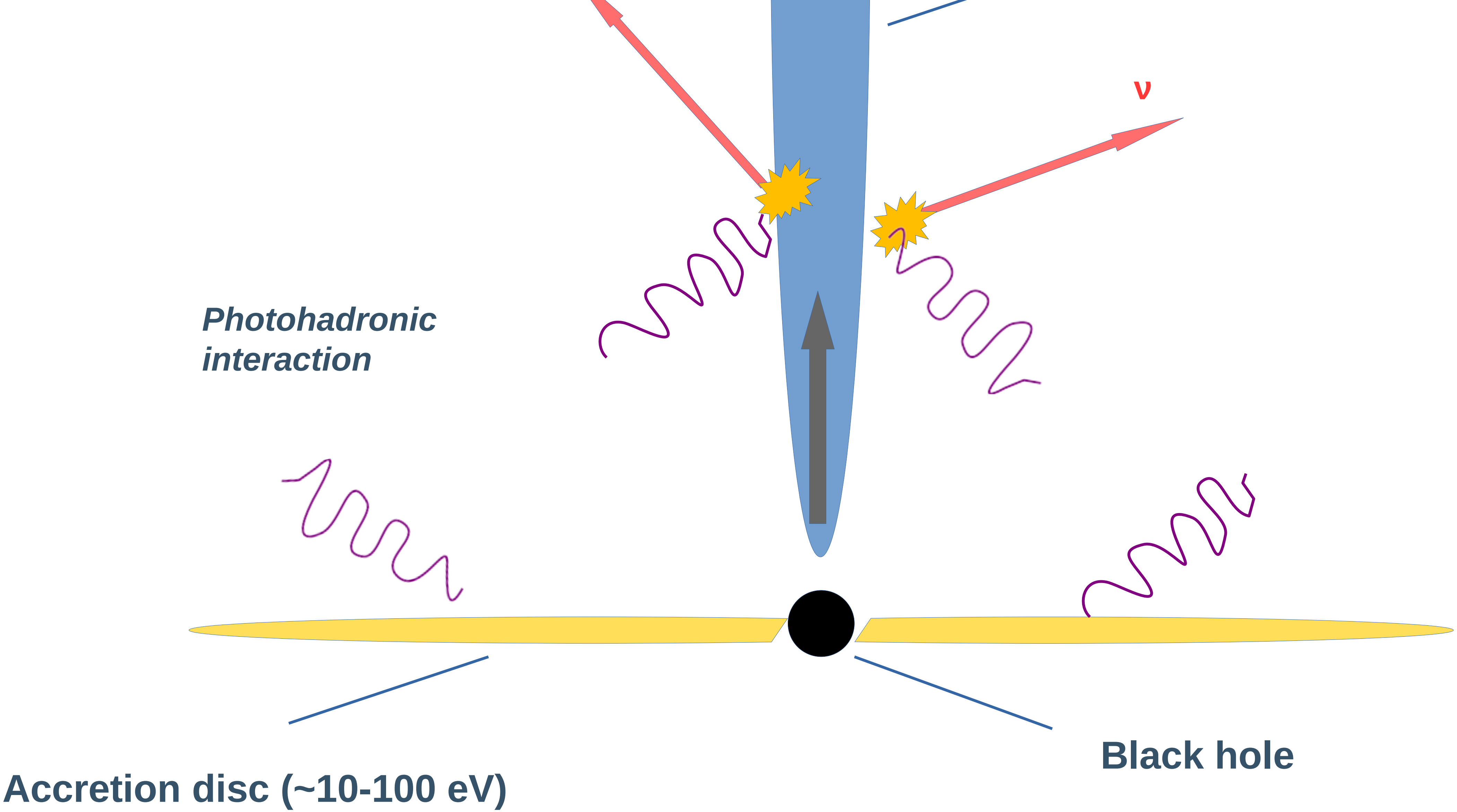
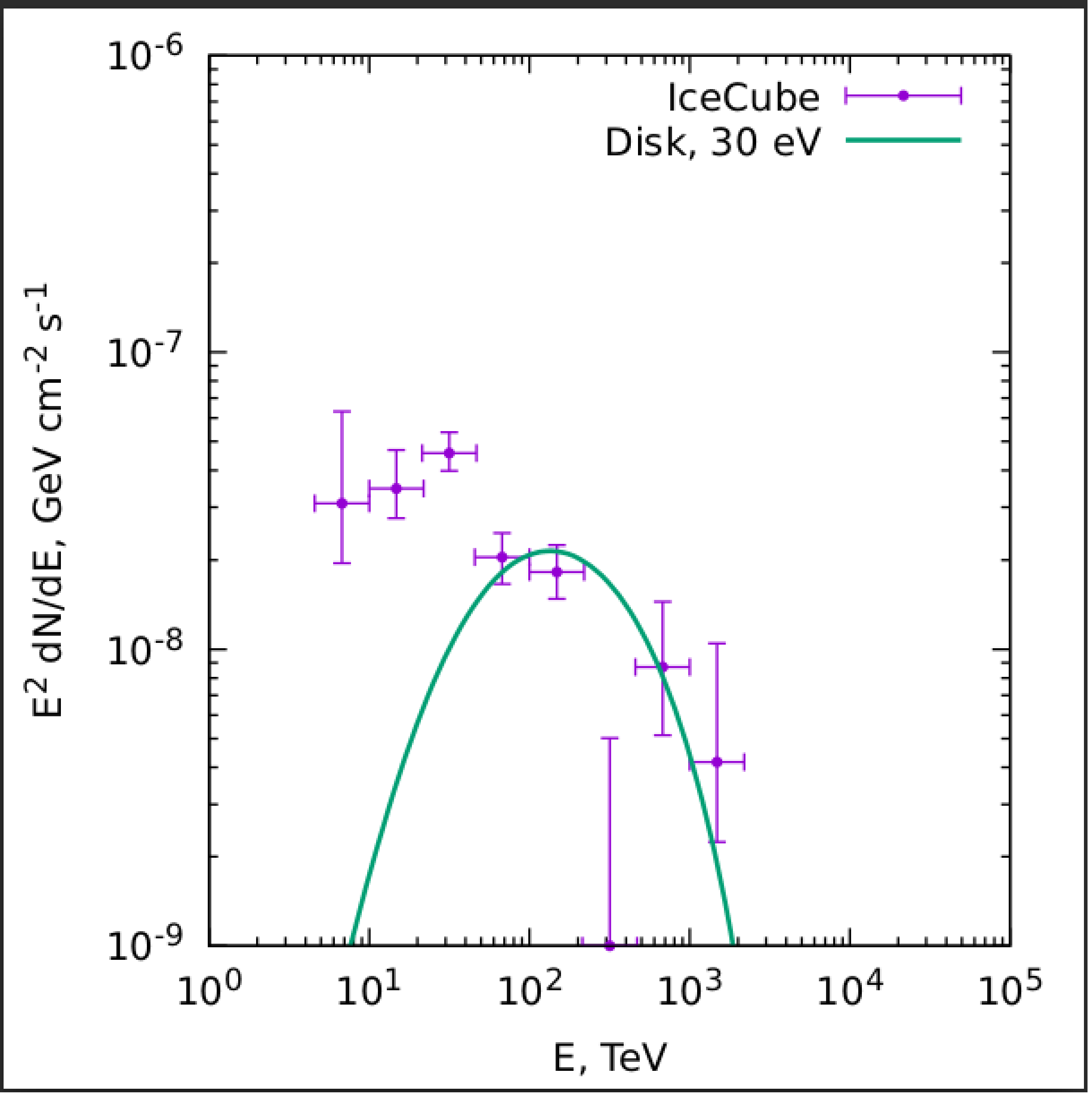
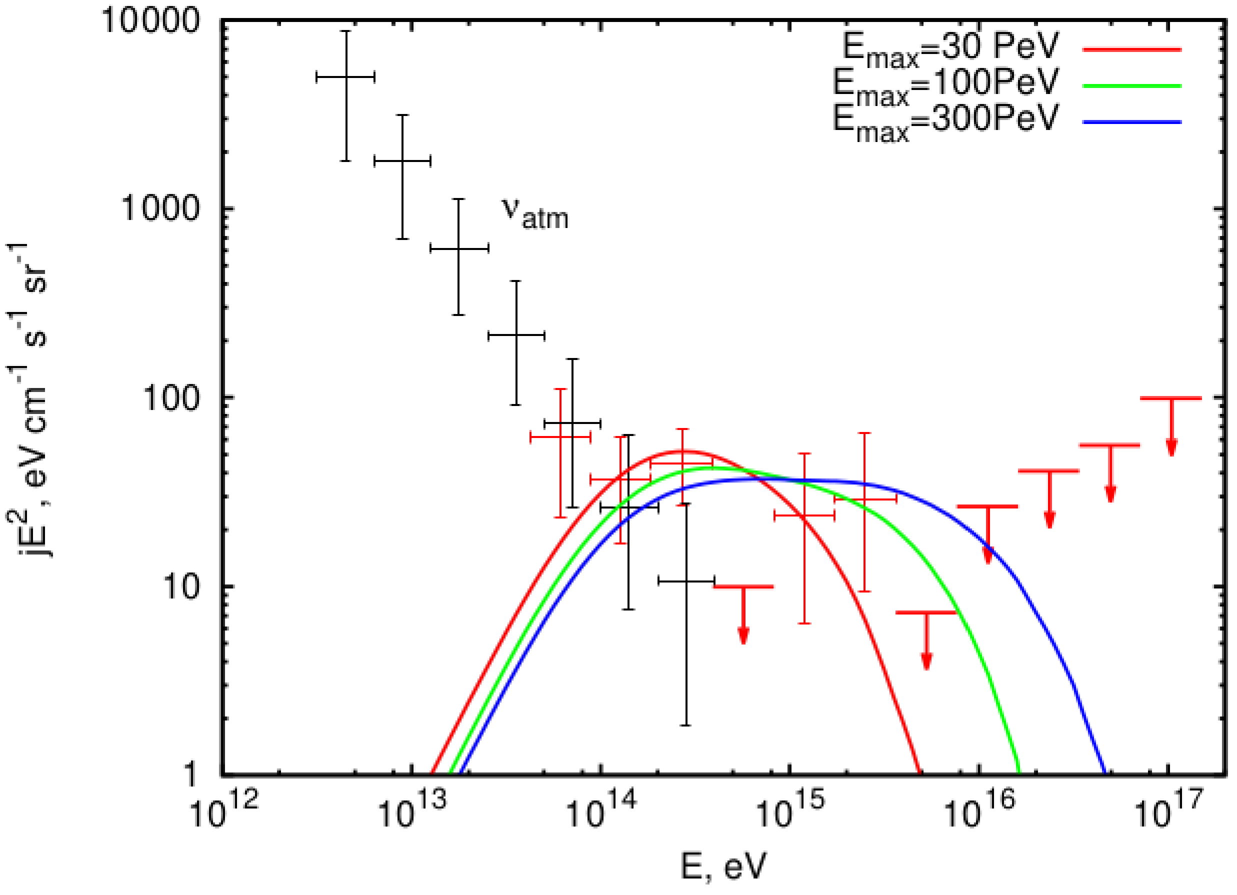
Content

Simple model of AGN



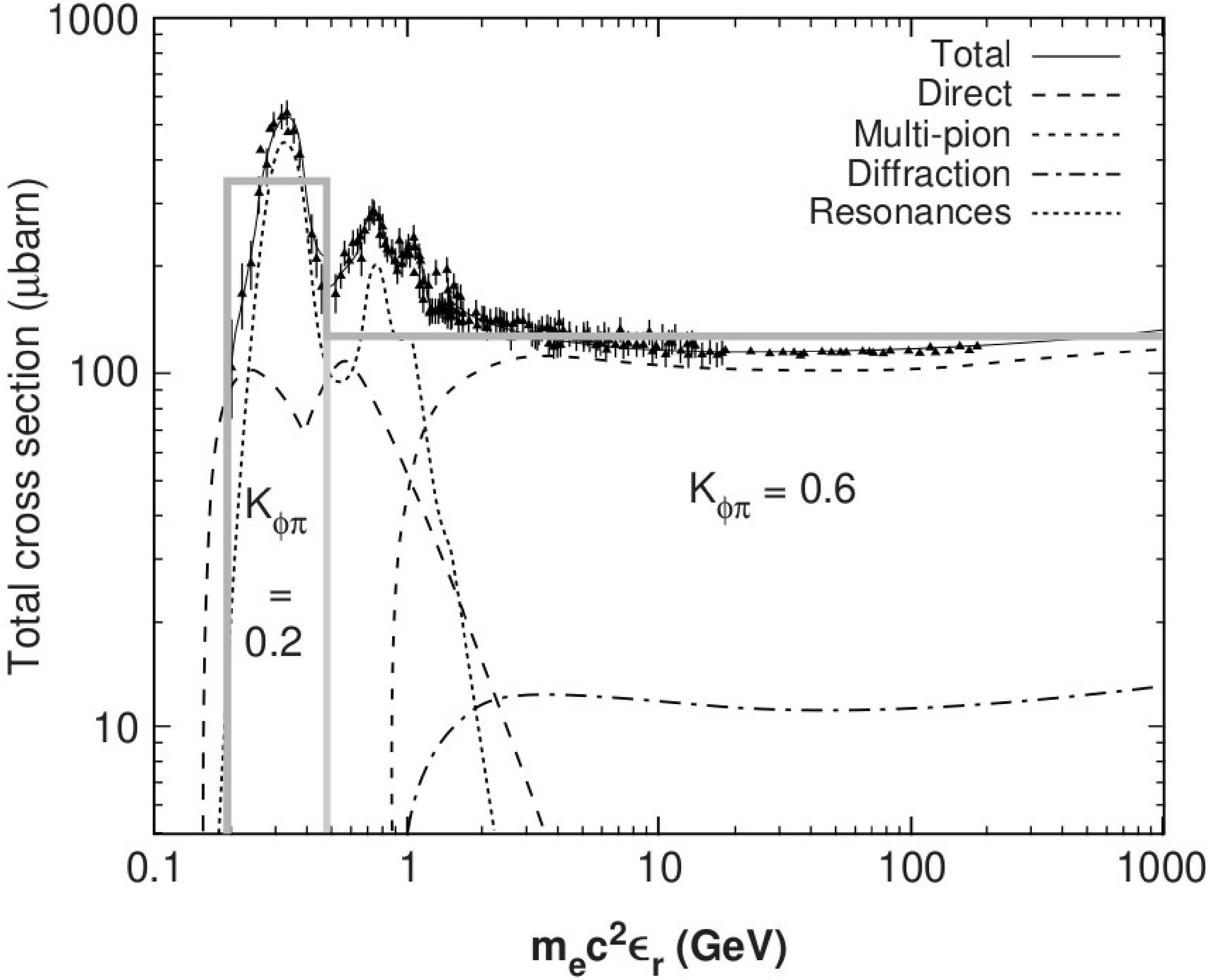




Kalashev, O., Semikoz, D., & Tkachev 2014 yr.

Reason: Energy threshold of photohadronic interactions.

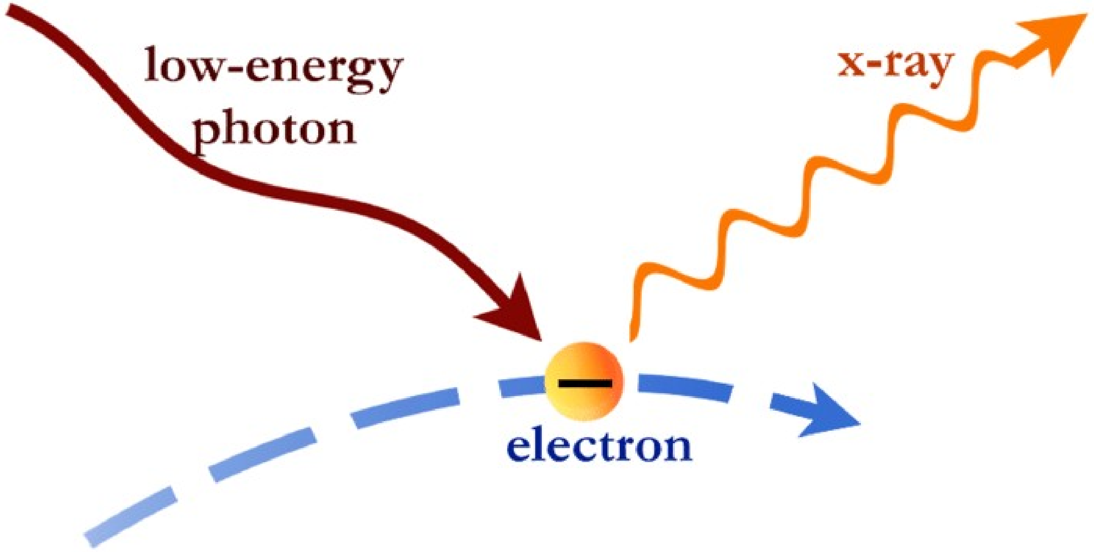
As the proton moves through the jet, its energy decreases. And at some point, the energy of the photons emitted from the disk is not enough to overcome the reaction threshold.

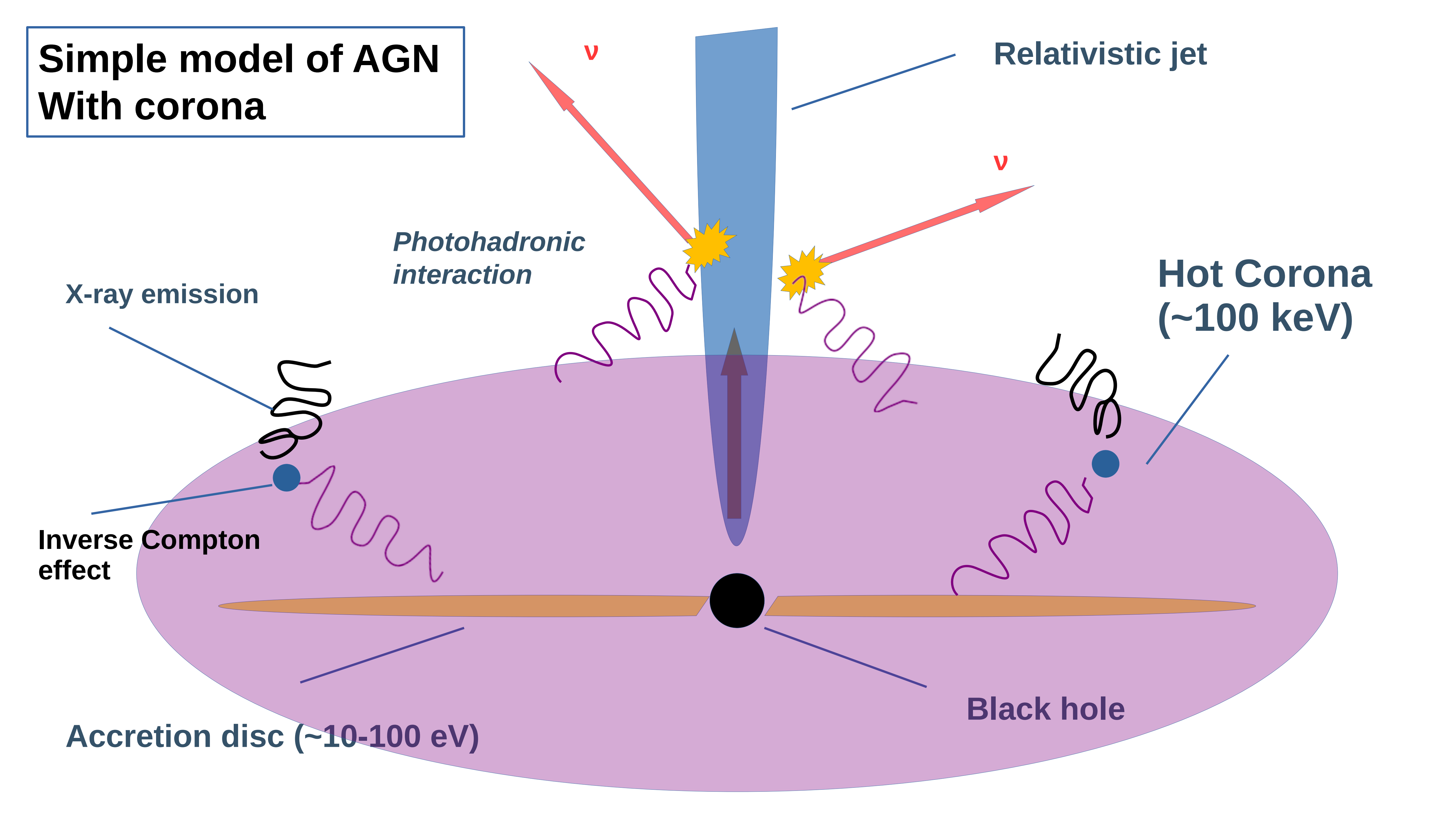


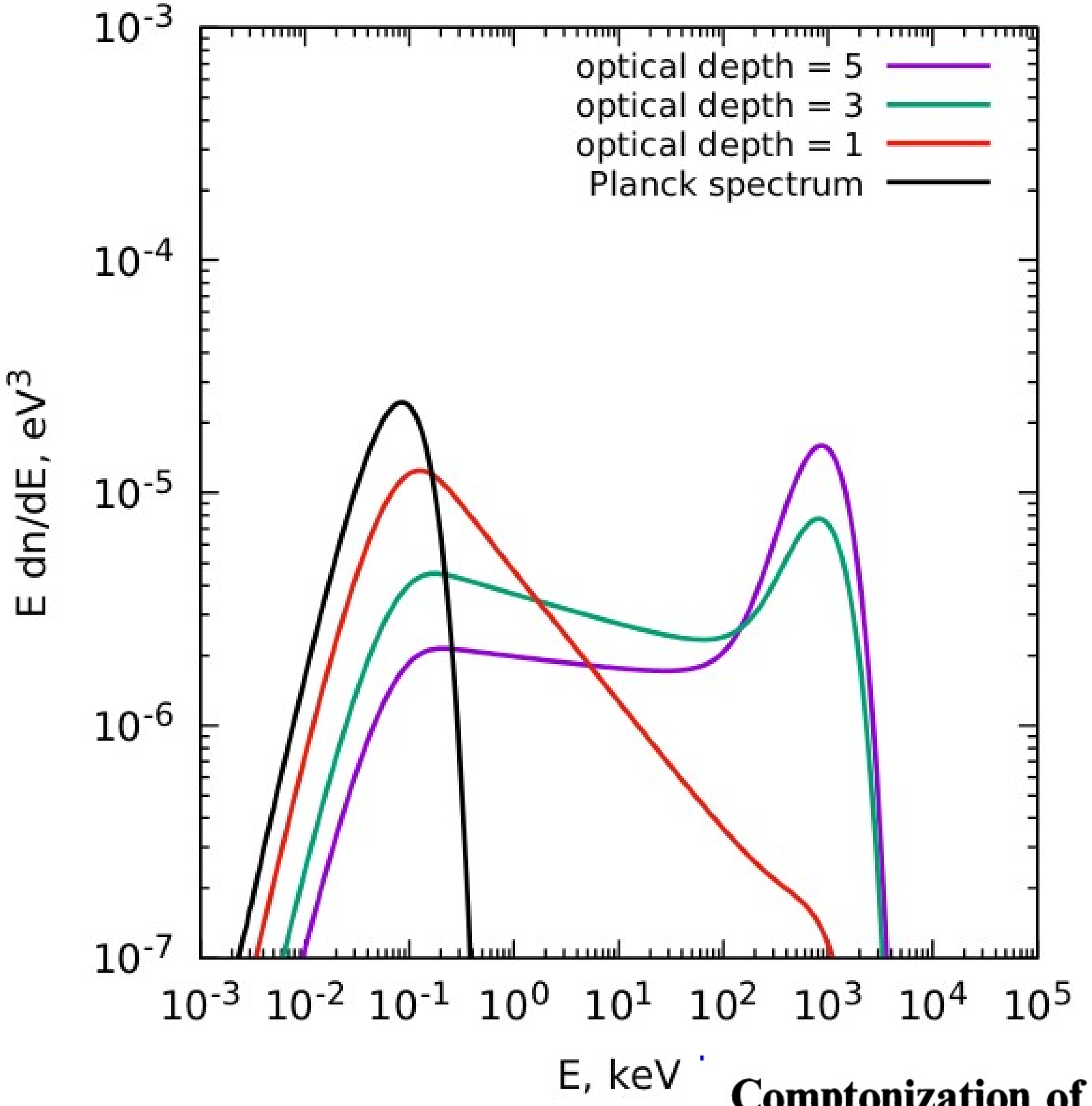
It's the main reason of "low-energy" (~100 TeV) cut-off

Therefore, it is necessary to add a pinch of high-energy photons, which could continue to further reduce the energy of protons and produce neutrinos of lower energies

The main idea: add electron plasma which can produce x rays photons via Compton effect




Simple model of AGN
With corona
ν
ν
Relativistic jet
Photohadronic
interaction
X-ray emission
Hot Corona
(~100 keV)
Inverse Compton
effect
Black hole
Accretion disc (~10-100 eV)



The final spectrum after escaping electron plasma cloud can be calculated:

$$F_\nu(x) = \int_0^\infty \frac{1}{x_0} G(x, x_0) f(x_0) dx_0$$

R.A. Sunyaev and L.G. Titarchuk, 1980

Comptonization of X-rays in Plasma Clouds. Typical Radiation Spectra

R. A. Sunyaev and L. G. Titarchuk

Space Research Institute, USSR Academy of Sciences, Profsoyuznaja 84/32, Moscow 117810, USSR

Received March 30, 1979

Reaction rate

$$R = \int d^3p \;\; n(p)\sigma(\omega)(1-\cos\theta)$$

Contribution of corona segment rdr to photon density at point z along a jet

$$n(\vec{p}) = \frac{\delta(\vec{n}-\vec{n_0})rdr}{r^2+z^2} n_c(p)$$

Corresponding reaction rate

$$R(z,r,E) = \frac{1-\cos\theta}{r^2+z^2} \int d^3p \;\; n_c(p)\sigma(\omega)$$

Reaction rate at point z from corona along jet

$$R(z,E) = \int r dr \frac{1-\cos\theta}{r^2+z^2} \int d^3p \;\; n_c(p)\sigma(\omega)$$

Sampling of proton optical depth and calculation of next interaction point

$$\tau_i = -\ln\xi$$

$$\tau_i = \int_{z_i}^{z_{i+1}} dz R(z,E)$$

Also photon momentum and interaction angle are sampled

SOPHIA

Monte-Carlo simulations of photohadronic processes in astrophysics

A. Mücke[1], Ralph Engel[2], J.P. Rachen[3,4],
R.J. Protheroe[1] and Todor Stanev[2]

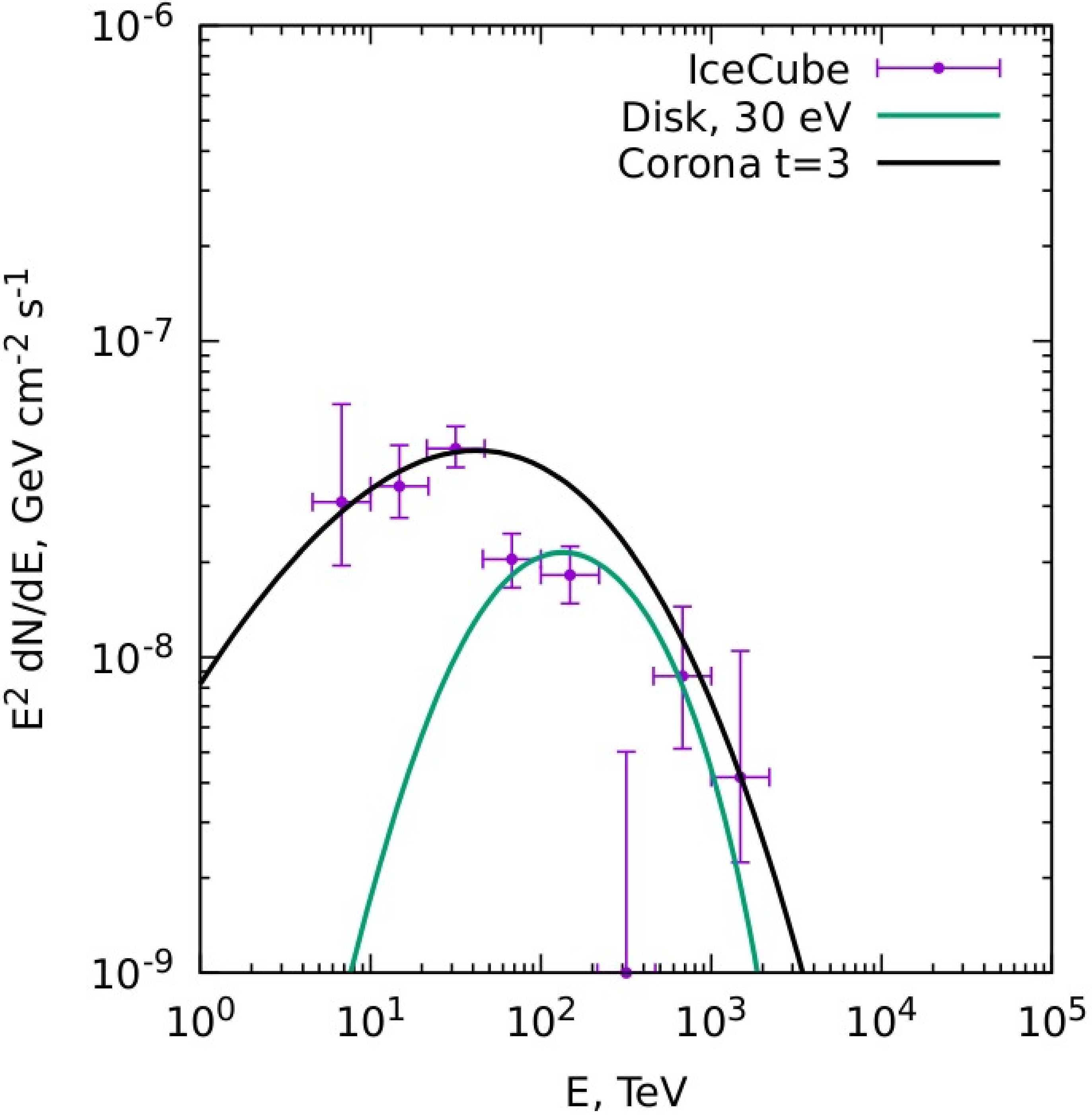
The SOPHIA code is used to model reactions between a high energy nucleon (or antinucleon) and a photon

1	n	14	0.197037E+07
2	p	13	0.606392E+08
3	gam	1	0.386169E+05
4	p bar	-13	0.864369E+07
5	num	17	0.263391E+05
6	numb	18	0.703644E+05
7	n bar	-14	0.446367E+06
8	num	17	0.623938E+05
9	numb	18	0.765029E+05
10	gam	1	0.724235E+07
11	gam	1	0.614287E+07
12	gam	1	0.133577E+07
13	gam	1	0.133492E+07
14	num	17	0.356544E+06
15	numb	18	0.236648E+05
16	p	13	0.376295E+06
17	num	17	0.744396E+06
18	nue	15	0.364177E+05
19	e+	2	0.486429E+05
20	numb	18	0.488836E+04

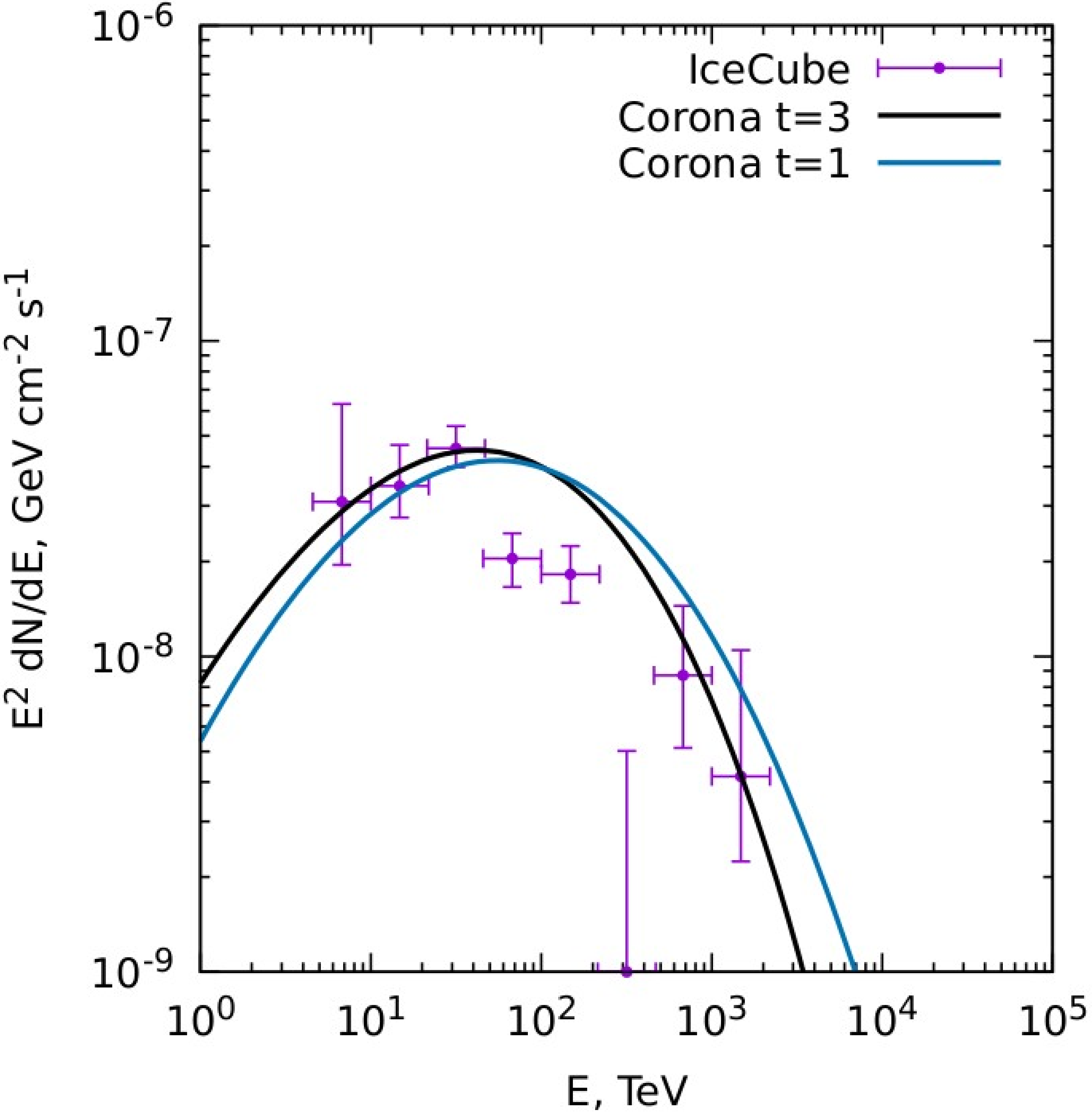
21	nueb	16	0.376394E+05
22	e-	3	0.484060E+06
23	num	17	0.385900E+05
24	num	17	0.464660E+05
25	nue	15	0.976494E+05
26	e+	2	0.138828E+05
27	numb	18	0.379252E+05
28	nueb	16	0.578797E+05
29	e-	3	0.498418E+05
30	num	17	0.104461E+06
31	numb	18	0.277022E+06
32	gam	1	0.254998E+07
33	gam	1	0.333406E+07
34	nue	15	0.148076E+05
35	e+	2	0.947082E+06
36	numb	18	0.230860E+06
37	nueb	16	0.246518E+05
38	e-	3	0.491881E+05
39	num	17	0.798465E+05
40	numb	18	0.268799E+05

40	numb	18	0.268799E+05
41	nue	15	0.665416E+06
42	e+	2	0.404345E+06
43	numb	18	0.289187E+06
44	nue	15	0.335697E+05
45	e+	2	0.924258E+04
46	numb	18	0.295447E+05
47	nueb	16	0.103170E+06
48	e-	3	0.160729E+06
49	num	17	0.127746E+06
50	nueb	16	0.131636E+05
51	e-	3	0.386214E+05
52	num	17	0.188199E+04

The typical products after one interaction between a 100PeV proton and a photon from the corona



IceCube
Disk, 30 eV
Corona t=3
E² dN/dE, GeV cm⁻² s⁻¹
E, TeV
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁰
10¹
10²
10³
10⁴
10⁵



IceCube
Corona t=3
Corona t=1
E2 dN/dE, GeV cm-2 s-1
E, TeV
10-6
10-7
10-8
10-9
100
101
102
103
104
105

Conclusions

1) The Monte Carlo approach was used for the first time to calculate the neutrino spectrum from the corona

2) It has been shown that the spectrum of the corona is capable of describing the spectrum of IceCube in the “low energy range” (1-100 TeV) and “high energy” tail (10^3-10^4 TeV)

Further calculations

1) Explore the spectrum for different geometries of the corona

2) Electron plasma temperature dependence

3) Model dependence on electron distribution

Thank for your attention!

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